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How many People may have Contracted COVID-19 and Whether any City has Reached Herd Immunity?

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Abstract

There is a high uncertainty regarding the prevalence of the COVID-19. We used a fast tracked straightforward method to estimate the prevalence of people contracted COVID-19 on a daily basis, which may rectify the official reports. We used the CDC's recent 'best estimate' regarding fatality ratios as a proxy to make the best estimate of the total number of symptomatic people based on the predicted number of probable deaths. There seems to be a big gap between the numbers of reported versus infected cases in major cities like New York City (NYC), Paris, Milan and London. We predict the prevalence of people who contracted SARS-CoV-2 seems to be up to 77% in NYC. Therefore, a significant proportion of NYC residents have already been infected, which implies that they may have reached the level of herd immunity protection (60%-70%). This would reduce the concern related to the possibility of reopening.

Introduction

It is still hard to know how many people have already been infected with SARS-CoV-2. Epidemiologists have already developed different prediction models that can be used as quantitative projections for the COVID-19. However, these epidemiologic models are impacted by uncertainty due to lack of adequate information regarding the total number of people who have contracted SARS-CoV-2 [1]. One of the reasons for the above challenge is the fact that approximately 35% of people infected with the COVID-19 are asymptomatic [2] and over 81% of those who are symptomatic have mild symptoms [3].

While testing is essential for reducing transmission by isolating infected cases, the question is; "to what extent the result of these non-randomized tests can inform us the total number of people infected with SARS-CoV-2?" Getting a better estimate regarding the prevalence of the COVID-19 can be used as a proxy to predict how far we are from getting herd immunity protection in major cities. Herd immunity is one of the ways to stop the virus transmission by conveying indirect protection to those who are not immune" [4]. The threshold for SARS-CoV-2 herd immunity seems to be around 60% in some areas [5].

Randomized population-based testing is a common method to estimate infection rate among the general population. These assessments are essential in order to quantify the overall prevalence of COVID-19. One study in Hauts-de-France has shown a seroprevalence of 3% as of April [6]. According to another study, 14% of people living in New York State [6], including over 2 million people in NYC (21%), had antibodies to SARS-CoV-2 by late April [7]. Researchers believe that the 21% infection rate seems not to be high enough to confer the 'herd immunity.'

These randomized antibody testing are less feasible to be implemented. These numbers will change over a short period of time. Therefore, these surveys need to be repeated frequent-

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ly. More importantly, not all types of antibody tests are at high quality, which means we can't completely rely on the seroprevalence results to predict the prevalence of COVID-19 in a lot of places with low prevalence.

We used a more practical approach to estimate the prevalence of COVID-19. This method is simple and straightforward, requires less inputs, and can make estimations at any region at any time. This approach can help epidemiologic models to have better and prompt input for their predictions. This will also help policy makers to have sufficient tools to make more efficient decisions. This approach may rectify the uncertain official reported infection rates for COVID-19 in the population.

The CDC has recently made a current 'best estimate' regarding viral transmission and disease severity in the United States. As stated by the CDC, overall, 0.4% of people 'who feel sick with Covid-19' would die in the 'best scenario' [6]. This fatality ratio differs depending on age. As claimed by CDC, the ratio is 0.0005 for people aged 0-49, 0.002 for people aged 50-64, and 0.013 for age 65 [2].

Given only six months have passed since the SARS-Cov-2 has initially infected humans, it is less likely that the nature of the virus and its fatality rate has completely changed due to mutation across different countries. Although, there may be some minor differences in fatality rate among countries. These differences would be minor given most of the countries in the US or Europe have been exposed to COVID-19 within a similar period of time. Therefore, we considered the CDC reported symptomatic fatality rates of the SARS-CoV-2 for different age groups as a basis for the fatality ratios of other targeted countries and cities listed in Table-1 and acknowledge that these rates may be slightly different in reality.

We used these fatality ratios as a proxy to make the best estimate of the total number of symptomatic people based on the total number of death cases. The challenge is that a substantial number of COVID-19 related death cases are missing. Therefore, it is very essential to have the best estimate of the number of probable death cases. Several countries have realized that their number of COVID- related death cases have been underreported. They have recently adjusted these numbers to include non-confirmed death cases by reporting 'excess mortality.' Excess mortality is the number of death cases which occurred 'in a given crisis above and beyond' what is expected to see under 'normal' conditions [8]. Getting access to information of the current excess mortality is challenging since there is a discrepancy among countries, particularly developing ones, on the number of reported deaths due to COVID-19. In addition, there is a delay of several weeks to months in reporting the total number of excess cases for instance, in Italy. This delay prevents accurate estimation of the magnitude of the current situation of COVID-19 in certain countries.

We used available data from different sources (such as *The Economist* database on Covid-19 excess mortality on GitHub) [9] on the number of confirmed COVID-19 deaths and number of excess deaths. We calculated the proportion of confirmed COVID-19 deaths (as of the most updated date, 6/7/2020) over excess death during the same time period. This helped us to identify the gap in order to predict the current number of excess deaths, which is needed to have the best estimate of the number of probable death cases as of today. We acknowledge that this proportion may change slightly toward having less gap over time, which would have a little impact on the achieved estimations.

Given the fatality ratio differs by age group, in order to estimate the total number of symptomatic infected cases, we used CDC and various national databases of the targeted countries indicated in Table 1, which included the number of deaths due to COVID-19 by age group, to calculate the proportion of confirmed COVID-19 related deaths by age group.

According to our findings in Table 1, the prevalence of people who contracted COVID-19 seems to be between 65% and 77% in NYC until August 26, 2020. Therefore, the number of people who have contracted COVID-19 are over 27 times the official reported number of people who have tested positive. This shows that there is a big gap between the numbers of reported versus number of infected cases. This gap is greater for other cities: 25 times for Ile-de-France (Paris), 27 times for Lombardy (Milan), and 50 times for London.

The virus has already moved very quickly through communities in these cities. In NYC, in addition to social distancing, another contributing factor in reducing the trend of mortality may be due to reaching the herd immunity threshold. This can be supported by the fact that the daily COVID-19 deaths count in NYC has recently decreased dramatically [10]. This could have happened through exposure in public, or most importantly, from direct exposure to their infected household members while they were in lockdown. Around 66% of newly admitted cases in NYC got infected from their household [11]. Our prediction implies that we are very close to the level of herd immunity protection (60%-70%) or have already reached it like New York City. This would be the case since CDC has also put 'lower estimates' for the overall fatality ratio (0.2%) in the 'least severe scenarios,' which would make the predicted prevalence even higher. In addition, we only estimated the number of symptomatic cases and we didn't include the number of asymptomatic cases, which would be as high as 35% of infected cases. Therefore, the real number of infected populations may be much higher.

In other hotspot cities like Milan and London, we estimate that overall 56% and 30% of the city population have already been infected with SARS-CoV-2 respectively. These predictions, using the best scenario, are aimed to assist public health preparedness and planning. Therefore, we may be able to resume public interactions and open businesses sooner than it was initially expected in some places like NYC if we assume that people who contracted SARS-CoV-2 are and will remain immune for a long time.

Highly affected cities like NYC or Milan can be opened sooner than other cities since they are close to reaching the level of 60% of the population who are infected with the SARS- CoV-2. However, it is important to consider some special measures in the process of opening these cities. For instance, should these cities be open to non-residents who have not been infected yet? In addition, we should consider whether those cities with high prevalence should be open to non-infected international tourists.

Reopening all provinces or cities of a country at the same time, which seems to be the case in several countries like Italy, Spain or France, would put less affected cities of those countries at greater risk of exposure. It is better not to use a centralized approach to open the businesses in a country or even a province since the decreasing number of deaths in those countries are more likely contributed to those major cities with high density.

25	Adjusted Estimated # of Symptomatic Infected People Based on **Confirmed** COVID-19 Deaths for Age Group (45-64 or 50-69) w (4)	10,69,412	13,19,281	5,39,517	3,24,445	5,97,701	64,04,243	9,07,264	25,06,176	16,25,496	34,21,339	6,13,101	20,66,115	6,63,858	26,31,603
26	Adjusted Estimated # of Symptomatic Infected People Based on **Excess** Deaths for Age Group (45-64 or 50-69) x (4)	12,57,034	16,62,096	9,47,916	6,65,300	14,32,734	90,14,434	2,84,690	7,98,436	7,13,176	12,07,171	3,75,985	8,94,266	1,94,933	7,07,203
27	Adjusted Estimated # of Symptomatic Infected People Based on **Confirmed** COVID-19 Deaths for Age Group (65+ or 70+) y (4)	3,24,111	4,61,450	1,72,509	1,63,330	1,59,388	26,32,384	2,20,901	6,09,721	2,66,590	5,60,560	1,39,381	4,69,935	1,22,896	4,88,844
28	Adjusted Estimated # of Symptomatic Infected People Based on **Excess** Deaths for Age Group (65+ or 70+) z (4)	3,80,974	5,81,357	3,03,093	3,34,920	3,82,064	37,05,270	2,47,559	6,93,748	4,17,732	7,06,377	3,05,271	7,26,426	1,28,882	4,69,176
29	Estimated # of Symptomatic Infected People Based on **Confirmed** COVID-19 Deaths for all age groups α	**54,93,393**	**67,02,214**	**33,36,789**	**19,37,592**	**37,89,835**	**3,75,46,797**	**18,65,654**	**51,08,410**	**28,81,031**	**41,14,536**	**36,59,442**	**1,22,61,128**	**14,31,958**	**57,31,424**
30	Estimated # of Symptomatic Infected People Based on **Excess Deaths** for all age groups β	**64,57,178**	**84,43,780**	**58,62,649**	**39,73,181**	**90,84,515**	**5,28,49,827**	**13,58,734**	**37,59,289**	**26,80,526**	**20,80,687**	**70,48,040**	**1,66,53,740**	**10,00,443**	**36,82,309**
31	Total Population (Country, State, City) (5)	83,99,000	1,94,50,000	3,95,10,000	2,14,80,000	########	33,10,02,651	75,56,900	5,59,77,178	1,00,60,000	6,04,61,826	66,42,000	4,67,54,778	1,22,10,000	6,52,73,511
32	Estimated Proportion of Symptomatic Infected Population based on **Confirmed** COVID-19 Deaths γ	**65%**	**34%**	**8%**	**9%**	**13%**	**11%**	**25%**	**9%**	**29%**	**7%**	**55%**	**26%**	**12%**	**9%**
33	Estimated Proportion of Symptomatic Infected Population based on the **Excess** Deaths δ	**77%**	**43%**	**15%**	**18%**	**31%**	**16%**	**18%**	**7%**	**27%**	**3%**	**106%**	**36%**	**8%**	**6%**
34	Proportion of Detected Cases/ Estimated Symptomatic Cases Infected with COVID-19 ε	**0.037**	**0.05**	**0.12**	**0.15**	**0.07**	**0.11**	**0.02**	**0.08**	**0.04**	**0.13**	**0.02**	**0.03**	**0.04**	**0.07**
35	# of People Who Have Contracted COVID-19/ # of People Who Have Been Tested Positive ζ	27	19	9	7	15	9	50	13	27	8	63	40	25	15
36	# of Total Tests Conducted (6)	-	-				1,98,11,243	-	3167470**	-	40,49,544	-	25,36,234	-	8,31,174
37	Proportion of Conducted COVID-19 Tests which have been Positive η	-	-				0.29	-	0.09	-	0.06	-	0.17	-	0.31

14	Proportion of **Confirmed** COVID-19 Deaths for age group (45-64 or 50-69)/Total **Confirmed** COVID-19 Deaths for all age groups l	0.2259	0.2030	0.2152	0.1512	0.2449	0.1784	0.0953	0.0953	0.135	0.1351	0.100	0.0998	0.121	0.1206
15	Predicted # of **Confirmed** COVID-19 Deaths for age group (45-64 or 50-69) m	5,347	6,596	2,698	1,622	2,989	32,021	1,270	3,509	2,276	4,790	858	2,893	929	3,684
16	# of **Confirmed** COVID-19 Deaths for age group (65+ or 70+) n (3)	15,240	24,607	8,571	7,878	7,393	1,30,082	-	39,741	-	30,429	-	16,774	-	17,762
17	Proportion of **Confirmed** COVID-19 Deaths for age group (65+ or 70+)/Total **Confirmed** COVID-19 Deaths for all age groups o	0.7394	0.7667	0.7430	0.8218	0.7054	0.7918	0.895	0.8943	0.854	0.8537	0.876	0.8759	0.864	0.8642
18	Predicted # of **Confirmed** COVID-19 Deaths for age group (65+ or 70+) p	17,502	24,918	9,315	8,820	8,607	1,42,149	11,929	32,925	14,396	30,270	7,527	25,376	6,636	26,398
19	Estimated # of Symptomatic Infected People Based on **Confirmed** COVID-19 Deaths q (4)	36,41,385	49,99,846	19,28,923	16,51,077	18,77,231	2,76,18,308	20,50,479	56,64,308	25,93,385	54,55,077	13,21,846	44,57,077	11,81,692	46,99,077
20	Estimated # of Symptomatic Infected People Based on **Excess** Deaths r (4)	42,80,246	62,99,053	33,89,067	33,85,660	44,99,861	3,88,74,762	22,97,922	64,44,917	40,63,683	68,74,093	28,95,089	68,89,760	12,39,245	45,10,018
21	Adjusted Estimated # of Symptomatic Infected People Based on **Confirmed** COVID-19 Deaths for Age Group (0-14 or 0-19) s (4)	0	0	0	0	0	20,76,248	44,427	82,849	61,809	1,32,638	21,76,640	73,12,089	76,810	3,51,982
22	Adjusted Estimated # of Symptomatic Infected People Based on **Excess** Deaths for Age Group (0-14 or 0-19) t (4)	0	0	0	0	0	29,22,470	49,788	94,266	96,851	1,67,140	47,67,247	1,13,03,044	80,551	3,37,821
23	Adjusted Estimated # of Symptomatic Infected People Based on **Confirmed** COVID-19 Deaths for Age Group (15-44 or 20-49) u (4)	40,99,870	49,21,483	26,24,763	14,49,816	30,32,746	2,64,33,921	6,93,062	19,09,664	9,27,135	0	7,30,320	24,12,989	5,68,394	22,58,996
24	Adjusted Estimated # of Symptomatic Infected People Based on **Excess** Deaths for Age Group (15-44 or 20-49) v (4)	48,19,170	62,00,326	46,11,639	29,72,960	72,69,716	3,72,07,653	7,76,698	21,72,839	14,52,767	0	15,99,537	37,30,004	5,96,077	21,68,109

Table 1

Geography (Location)		New York City	New York State	CA	Florida	Texas	USA	London	England	Lombardy (including Milan)	Italy	Madrid	Spain	Ile-de-France (including Paris)	France
#	Description	Cases	Cases	Cases	Cases	Cases	Cases	Cases	Cases	Cases	Cases	Cases	Cases	Cases	Cases
1	# of **Confirmed** COVID-19 Deaths a (1)	23,506	32,388	9,357	7,019	6,835	1,52,611	8,527	48,958	16,589	33,991	8,539	28,754	11,457	30,025
2	# of **Confirmed** COVID-19 Deaths until 8/26/20 *(2)	23,669	32,499	12,538	10,732	12,202	1,79,519	13,328	36,818	16,857	35,458	8,592	28,971	7,681	30,544
3	# of **Confirmed** COVID-19 Infected Cases until 8/26/20 *(2)	2,37,525	4,36,063	6,87,227	6,08,714	6,18,267	58,00,000	27,124	2,84,155	98,818	2,62,540	1,12,514	4,19,849	40,647	2,53,587
4	# of **Excess** Deaths b [1]	27,630	40,804	16,440	14,393	16,384	2,14,811	9,556	55,705	25,994	42,833	18,702	44,448	12,015	28,817
5	Proportion of **Confirmed** COVID-19 Deaths/**Excess** Deaths c	85%	79%	57%	49%	42%	71%	89%	88%	64%	79%	46%	65%	95%	104%
6	Predicted # of **Excess** Deaths until 8/26/20 d	27,822	40,944	22,029	22,007	29,249	2,52,686	14,936	41,892	26,414	44,682	18,818	44,783	8,055	29,315
7	# of **Confirmed** COVID-19 Deaths for age group (0-14 or 0-19) e (3)	0	0	0	0	0	57	-	3	-	4	-	145	-	7
8	Proportion of **Confirmed** COVID-19 Deaths for age group (0-14 or 0-19)/Total **Confirmed** COVID-19 Deaths for all age groups f	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0001	0.0001	0.0001	0.0001	0.008	0.0076	0.000	0.0003
9	Predicted # of **Confirmed** COVID-19 Deaths for age group (0-14 or 0-19) g	0	0	0	0	0	62	1	2	2	4	65	219	2	11
10	# of **Confirmed** COVID-19 Deaths for age group (15-44 or 20-49) h (3)	714	972	483	259	521	4,838		461	-	396	-	319	-	304
11	Proportion of **Confirmed** COVID-19 Deaths for age group (15-44 or 20-49)/Total **Confirmed** COVID-19 Deaths for all age groups i	0.0346	0.0303	0.0419	0.0270	0.0497	0.0294	0.0104	0.0104	0.011	0.0111	0.017	0.0167	0.015	0.0148
12	Predicted # of **Confirmed** COVID-19 Deaths for age group (15-44 or 20-49) j	820	984	525	290	607	5,287	139	382	185		146	483	114	452
13	# of **Confirmed** COVID-19 Deaths for age group (45-64 or 50-69) k (3)	4,656	6,514	2,482	1,449	2,567	29,303	-	4,235	-	4,815	-	1,912	-	2,479

Footnotes

(a) # of Confirmed Deaths due to COVID-19 from the first week of March until: US 8/1/20, England 8/14/20, France 7/14/20, Spain 8/25/20, and Italy 6/30/20.

(b) # of Excess Deaths from first week of March until: US 8/1/20, England 8/14/20, France 7/14/20, Spain 8/25/20, and Italy 6/30/20.

(c) Proportion of Confirmed COVID-19 Deaths/Excess Deaths from the first week of March until: US 8/1/20, England 8/14/20, France 7/14/20, Spain 8/25/20, and Italy 6/30/20 Formula: X1/X4 (# of Confirmed COVID-19 Deaths/# of Excess Deaths).

Note

X: Represents respective cell for each column used in each formula.

(d) Predicted # of Excess Deaths until 8/26/20 * Except the USA until Formula: X2*(1/X5) (# of Confirmed COVID-19 Deaths until 6/7/20)*(1/Proportion of Confirmed COVID-19 Deaths/Excess Deaths)).

(e) # of Confirmed COVID-19 Deaths for: age (0-19) year for France and Spain until 8/26/20, and Italy until 8/25/20; age (0-14) for the USA until 8/22/20 and England until 7/30/20.

(f) Formula: X7/(X7+X10+X13)(# of Confirmed COVID-19 Deaths for age group (0-14 or 0-19) / ((# of Confirmed COVID-19 Deaths for age group (0-14 or 0-19) + # of Confirmed COVID-19 Deaths for age group (15-44 or 20-49) + # of Confirmed COVID-19 Deaths for age group (45-64 or 50-69) + # of Confirmed COVID-19 Deaths for age group (65+ or 70+))

(g) Formula: X8*X2 ((Proportion of Confirmed COVID-19 Deaths for age group (0-44 or 0-49)/Total Confirmed COVID-19 Deaths for all age groups) * # of Confirmed COVID-19 Deaths until 6/7/20).

(h) # of Confirmed COVID-19 Deaths for: age (20-49) year for France and Spain until 8/26/20, and Italy until 8/25/20; age (15-44) for the USA until 8/22/20 and England until 7/30/20.

(i) Formula: X7/(X7+X10+X13) (# of Confirmed COVID-19 Deaths for age group (15-44 or 20-49) / ((# of Confirmed COVID-19 Deaths for age group (0-14 or 0-19) + # of Confirmed COVID-19 Deaths for age group (15-44 or 20-49) + # of Confirmed COVID-19 Deaths for age group (45-64 or 50-69) + # of Confirmed COVID-19 Deaths for age group (65+ or 70+))

(j) Formula: X8*X2 ((Proportion of Confirmed COVID-19 Deaths for age group (15-44 or 20-49)/Total Confirmed COVID-19 Deaths for all age groups) * # of Confirmed COVID-19 Deaths until 8/26/20).

(k) # of Confirmed COVID-19 Deaths for: age (50-69) year for France and Spain until 8/26/20, and Italy until 8/25/20; age (45-64) for the USA until 8/22/20 and England until 7/30/20.

(l) Formula: X10/(X7+X10+X13) (# of Confirmed COVID-19 Deaths for age group (45-64 or 50-69) / ((# of Confirmed COVID-19 Deaths for age group (0-14 or 0-19) + # of Confirmed COVID-19 Deaths for age group (15-44 or 20-49) + # of Confirmed COVID-19 Deaths for age group (45-64 or 50-69) + # of Confirmed COVID-19 Deaths for age group (65+ or 70+)).

(m) Formula: X11*X2 ((Proportion of Confirmed COVID-19 Deaths for age group (45-64 or 50-69)/Total Confirmed COVID-19 Deaths for all age groups) * # of Confirmed COVID-19 Deaths until 6/7/20).

(n) # of Confirmed COVID-19 Deaths for: age (70+) year for France and Spain until 8/26/20, and Italy until 8/25/20; age (65+) for the USA until 8/22/20 and England until 7/30/20.

(o) Formula: X13.(X7+X10+X13) (# of Confirmed COVID-19 Deaths for age group (65+ or 70+) / (# of Confirmed COVID-19 Deaths for age group (0-14 or 0-19) + # of Confirmed COVID-19 Deaths for age group (15-44 or 20-49) + # of Confirmed COVID-19 Deaths for age group (45-64 or 50-69) + # of Confirmed COVID-19 Deaths for age group (65+ or 70+)).

(p) Formula: X14*X2 ((Proportion of Confirmed COVID-19 Deaths for age group (65+ or 69+)/Total Confirmed COVID-19 Deaths for all age groups) * # of Confirmed COVID-19 Deaths until 6/7/20).

(q) Estimation made using CDC Overal COVID-19 Fatality Rate of 0.004 until 8/26/20 Formula: X2*(1/0.004) (# of Confirmed COVID-19 Deaths until 8/26/20 * (1/0.004)).

(r) Formula: X6*250 (Predicted # of Excess Deaths until 8/26/20 * 250).

(s) Adjusted estimation made Using CDC COVID-19 Fatality Ratio (0.00003) for Age Group (0-14 or 0-19) until 8/26/20 Formula: (1/0.00003)*X9 ((1/0.00003) * Predicted # of Confirmed COVID-19 Deaths for age group (0-14 or 0-19)).

(t) Formula: (1/X5)*((1/0.00003)*X9) ((1/Proportion of Confirmed COVID-19 Deaths/Excess Deaths) * ((1/0.00003) * Predicted # of Confirmed COVID-19 Deaths for age group (0-14 or 0-19)).

(u) Adjusted estimation made Using CDC COVID-19 Fatality Ratio (0.0002) for Age Group (15-44 or 20-49) until 8/26/20 Formula: (1/0.0002)*X12 ((1/0.0002) * Predicted # of Confirmed COVID-19 Deaths for age group (15-44 or 20-49)).

(v) Formula: (1/X5)*((1/0.0002)*X12) ((1/Proportion of Confirmed COVID-19 Deaths/Excess Deaths) * ((1/0.0002) * Predicted # of Confirmed COVID-19 Deaths for age group (15-44 or 20-49)).

(w) Adjusted estimation made Using CDC COVID-19 Fatality Ratio (0.005) for Age Group (45-64 or 50-69) until 8/26/20 Formula: (1/0.005)*X15.

(x) Formula: (1/X5)*((1/0.005)*X12) ((1/Proportion of Confirmed COVID-19 Deaths/Excess Deaths) * ((1/0.005) * Predicted # of Confirmed COVID-19 Deaths for age group (45-64 or 50-69)) .

(y) Adjusted estimation made Using CDC COVID-19 Fatality Ratio (0.054) for Age Group (65+ or 70+) until 8/26/20 Formula: (1/0.054)*X15.

(z) Formula: (1/X5)*((1/0.054)*X15) ((1/Proportion of Confirmed COVID-19 Deaths/Excess Deaths) * Predicted # of Confirmed COVID-19 Deaths for age group (65+ or 70+)).

(α) Estimation made for All Age Groups Using CDC COVID-19 Fatality Ratio: (0.00003) for Age Group (0-14 or 0-19) + (0.0002) for Age Group (15-44 or 20-49) + (0.005) for Age Group (45-64 or 50-69) +(0.054) for Age Group (65+ or 70+) all until 8/26/20 Formula: X18+X20+X22 (Adjusted Estimated # of Symptomatic Infected People Based on Confirmed COVID-19 Deaths for Age Group (0-14 or 0-19) + Adjusted Estimated # of Symptomatic Infected People Based on Confiremed COVID-19 Deaths for Age Group (15-44 or 20-49) + Adjusted Estimated # of Symptomatic Infected People Based on Confirmed COVID-19 Deaths for Age Group (45-64 or 50-69)) + Adjusted Estimated # of Symptomatic Infected People Based on Confirmed COVID-19 Deaths for Age Group (65+ or 70+)).

(β) Formula: X19+X21+X23 (Adjusted Estimated # of Symptomatic Infected People Based on Excess Deaths for Age Group (0-44 or 0-49) + Adjusted Estimated # of Symptomatic Infected People Based on Excess Deaths for Age Group (45-64 or 50-69) + Adjusted Estimated # of Symptomatic Infected People Based on Excess Deaths for Age Group (65+ or 69+)).

(γ) Until 8/26/20 Formula: X24/X26 (Estimated # of Symptomatic Infected People Based on Confirmed COVID-19 Deaths for all age groups/Total Population).

(δ) Until 8/26/20 Formula: X25/X26 (Estimated # of Symptomatic Infected People Based on Excess Deaths for all age groups/Total Population).

(ε) Formula: X3/X25 (# of Confirmed COVID-19 Infected Cases until 8/26/20/ stimated # of Symptomatic Infected People Based on Excess Deaths for all age groups).

(ζ) Formula: 1/X29 (1/Proportion of Detected Cases/Estimated Symptomatic Cases Infected with COVID-19).

(η) Formula: X3/X31 (# of Confirmed COVID-19 Infected Cases until 8/26/20/# of Total Tests Conducted).

Data sources

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(6) Total tests conducted: https://ourworldindata.org/grapher/daily-cases-covid-19 **Total tests conducted in UK instead of England.

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